Predicting Tropical Cyclone Genesis

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Award Number: N0001410WX20210, N0001410WX20887

LONG-TERM GOALS

The long-term goal of this project is to provide probabilistic genesis forecast guidance to operational forecasters and develop a genesis index to provide guidance for operational dynamical model prediction of tropical cyclone (TC) genesis. Once regions of high TC genesis probability are identified, a movable, multi-nested version of the COAMPS®[1] with resolution of roughly 3 km or less in the inner most grid will be utilized for predicting the genesis event.

OBJECTIVE

The objective of this project is to develop a statistical TC genesis model that is capable of separating developing and non-developing tropical disturbances. A TC genesis index will be constructed to provide the probability of cyclogenesis, based on NOGAPS global analysis and forecast fields.

APPROACH

Our approach is to identify distinctive characteristics associated with developing and non-developing disturbances in the tropical western North Pacific and Atlantic oceans. A box-difference index (BDI) is introduced to quantitatively determine the relative importance of dynamic and thermodynamic parameters in determining the genesis events. Once key genesis parameters in different basins are

[1] COAMPS® is a registered trademark of the Naval Research Laboratory.

Report Documentation Page						*Form Approved OMB No. 0704-0188*
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1. REPORT DATE **2010**		2. REPORT TYPE				3. DATES COVERED **00-00-2010 to 00-00-2010**
4. TITLE AND SUBTITLE **Predicting Tropical Cyclone Genesis**						5a. CONTRACT NUMBER
						5b. GRANT NUMBER
						5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)						5d. PROJECT NUMBER
						5e. TASK NUMBER
						5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,7 Grace Hopper Avenue,Monterey,CA,93943-5502**						8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)						10. SPONSOR/MONITOR’S ACRONYM(S)
						11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT						
15. SUBJECT TERMS						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**		

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

determined, then we will develop a nonlinear logistic regression method for TC genesis probability forecast at different basins.

WORK COMPLETED

In the past year, we primarily worked on (1) refining genesis predictors and constructing a nonlinear regression model, (2) evaluating the model performance by conducting hindcast TC genesis forecasts in the WNP for year 2009, and (3) extending the approach to the North Atlantic.

A critical factor that affects the performance of a statistical prediction model is the selection of predictors. Previously there were 11 predictors. To overcome the overfitting problem, we intentionally decreased the number of predictors. A BDI methodology (which takes into account of both the mean and spreading of samples within the developing and non-developing groups) was applied to objectively and optimally determine the best predictors for the regression model.

The hindcast of WNP TC genesis during 2009 summer with the refined genesis forecast model shows a much improved result, with a hit rate of 72.2% and a false alarm rate of only 19.2%. The detailed results will be presented next section.

The methodology is now extended to the North Atlantic. A preliminary calculation shows that the BDI-based Atlantic genesis forecast model has a quite high in-sample hindcast skill.

RESULTS

With use of the previous 11 predictor model, we conducted the cyclogenesis hindcast experiment for summer of 2009. Figure 1 shows the genesis potential index for all developing and non-developing cases in 2009. It turns out that the hitting rate is quite low (33%).

The model was refined with the BDI-based methodology. For a given variable (say, the relative humidity at 700hPa), the BDI is defined as following:

$$BDI = \frac{M_{DEV} - M_{NONDEV}}{\sigma_{DEV} + \sigma_{NONDEV}} \ ,$$

where M_{DEV} and σ_{DEV} (M_{NONDEV} and σ_{NONDEV}) represent the mean and standard deviation of the variables for the developing (non-developing) cases.

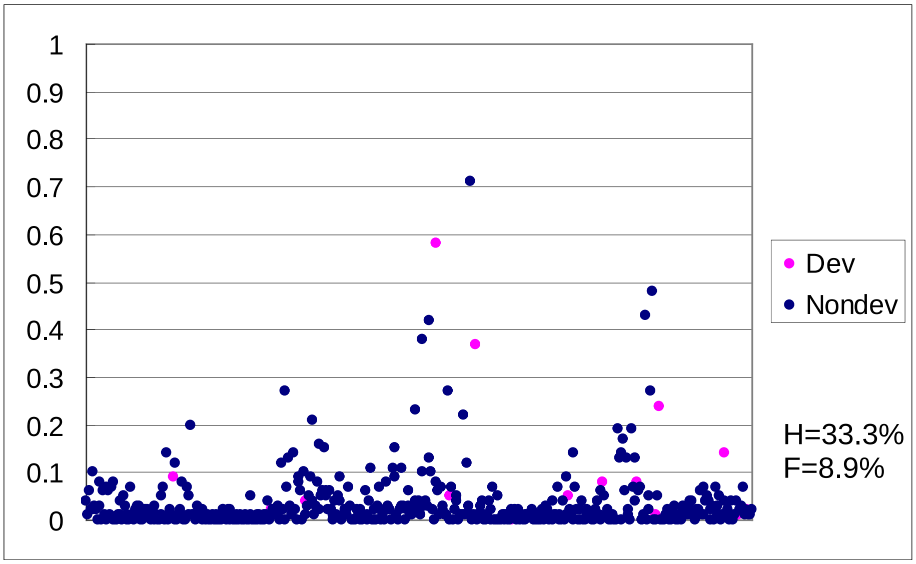

Fig. 1 Forecasted genesis index for WNP disturbances in 2009 summer with use of the previous 11 predictor model. Pink dots are for developing cases and blue dots are for non-developing cases. Hit rate and False alarm rate are represented by 'H' and 'F'.

We calculated BDI of a number of important genesis parameters for the WNP, based on the NOGAPS analysis fields during 2003-2008. Table 1 lists key genesis parameters in the WNP.

Table 1 BDI of key genesis parameters in the WNP.

Variable name	BDI	
	sign	magnitude
Maximum 800 hPa vorticity	+	0.46
Rain rate (20°x20°)	+	0.42
800/750 hPa du/dy (10°x10°)	–	0.41
1000 hPa Divergence (10°x10°)	–	0.37
950 hPa relative humidity (10°x10°)	+	0.27
925-400 hPa integrated specific humidity (10°x10°)	+	0.24
SST (20°x20°)	+	0.13
Translational speed	–	0.06

While the sign of the BDI reflects the physical nature of a variable, the magnitude of the BDI measures to what extent the variable is capable of differentiating the developing and non-developing disturbance groups. The greater the BDI amplitude is, the better a variable can be used to predict whether or not cyclogenesis will happen.

Based on the table above, we reduce the predictor number from 11 to 8 and replace some of previous predictors with top BDI parameters. Figure 2 shows the 2009 forecast results with the refined genesis prediction model. Same as before, we set threshold as 0.2. The hitting rate increases to 72%, while the false alarm rate is kept about 19%.

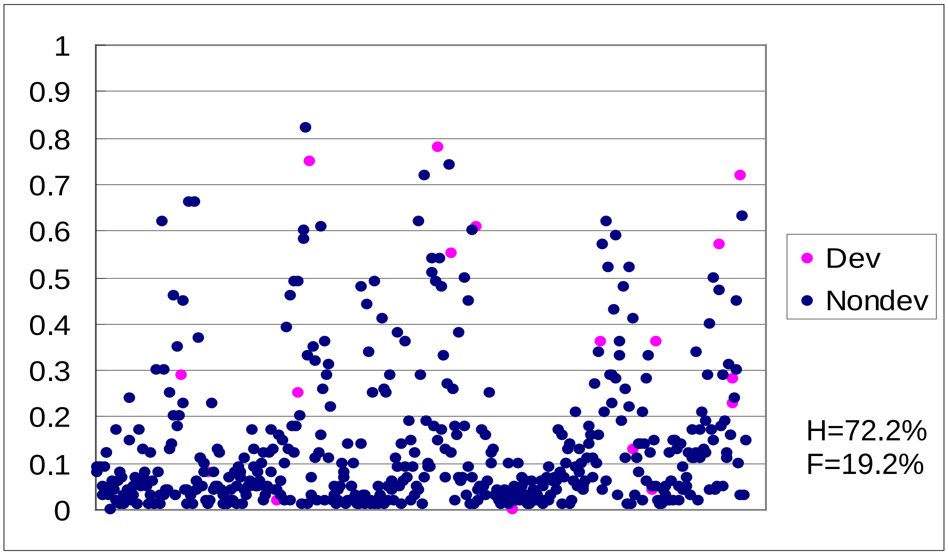

Fig. 2 Same as Fig. 1 except for the refined genesis model.

Table 2 BDI of key genesis parameters in the North Atlantic

Variable name	BDI	
	sign	magnitude
925 - 400 hPa water vapor content (10° x 10°)	+	0.49
750 hPa relative humidity (10° x 10°)	+	0.44
Rain rate (20° x 20°)	+	0.35
750 hPa Divergence (20° x 20°)	–	0.35
SST (20° x 20°)	+	0.33
Maximum 700 hPa relative vorticity	+	0.32
600 hPa du/dy (10° x 10°)	–	0.23
600-1000 hPa vertical shear (20° x 20°)	–	0.19
Translational speed	–	0.07

The same methodology was also applied to cyclogenesis in North Atlantic. Table 2 lists top genesis parameters and their BDI values in the North Atlantic.

Based on the BDI information, we select a set of predictors for Atlantic TC genesis forecast model. Following the same procedures as in constructing the WNP model, we derived a regression model for the North Atlantic. Figure 3 showed the in-sample validation for the Atlantic model during 2003-2008. It shows a hitting rate of 65.3% and a false alarm rate of 20.0%. Next we will conduct hindcast for Atlantic TCs in 2009-2010.

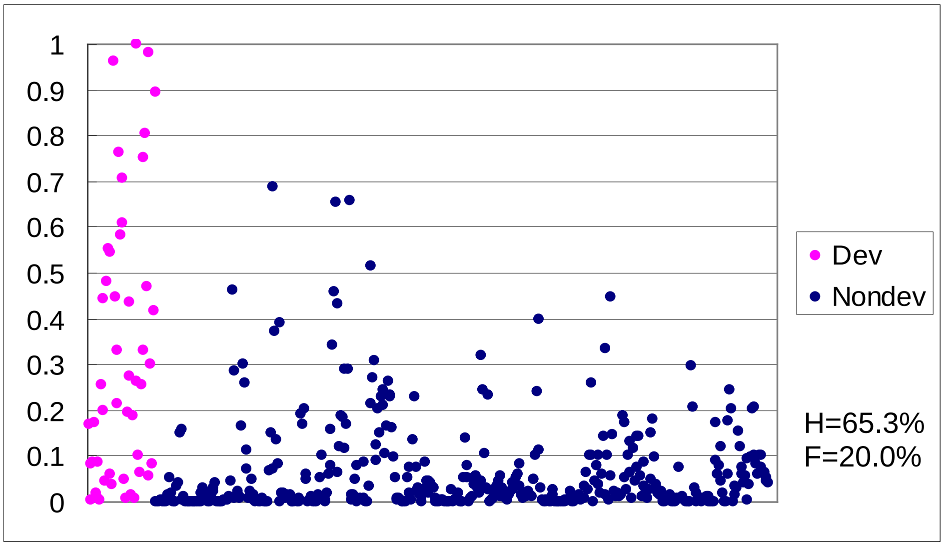

Fig. 3 In-sample validation of a North Atlantic genesis forecast model for the period of 2003-2008. Pink dots are developing cases and blue dots are non-developing cases. Hit rate and False alarm rate are represented by 'H' and 'F'.

IMPACT/APPLICATIONS

The successful completion of this project may provide an operational TC genesis probability forecast system based on the NOGAPS global analysis and forecast fields. Operational TC forecast centers may use this product as a reference for issuing a TC formation alert/warning at a lead of 24-72 hours. This product can also provide guidance about where to place a high-resolution regional model (such as COAMPS) for dynamic TC genesis prediction.

TRANSITIONS

The forecast models developed by this project may readily transition to a 6.4 project for quasi-operational tests.

RELATED PROJECTS

This project is closely related to the NRL 6.2 funding on "Predicting tropical cyclone genesis using NOGAPS". Knowledge gained from this project will help to improve the prediction of tropical cyclone genesis.

PUBLICATIONS

Peng, M. S., B. Fu, T. Li, and D. E. Stevens, 2010: Developing versus non-developing disturbances for tropical cyclone formation. Part I: North Atlantic. *Submitted to Monthly Weather Review*.

Fu, B., M. S. Peng, T. Li, and D. E. Stevens, 2010: Developing versus non-developing disturbances for tropical cyclone formation. Part II: Western North Pacific. *Submitted to Monthly Weather Review*.